



Ecological Specialization and Craniofacial Evolution in Deep-Channel Ghost Electric Fishes (Navajini, Apteronotidae)

Jonathan G. Allen, James S. Albert

University of Louisiana at Lafayette, Louisiana, USA

Introduction and Aim

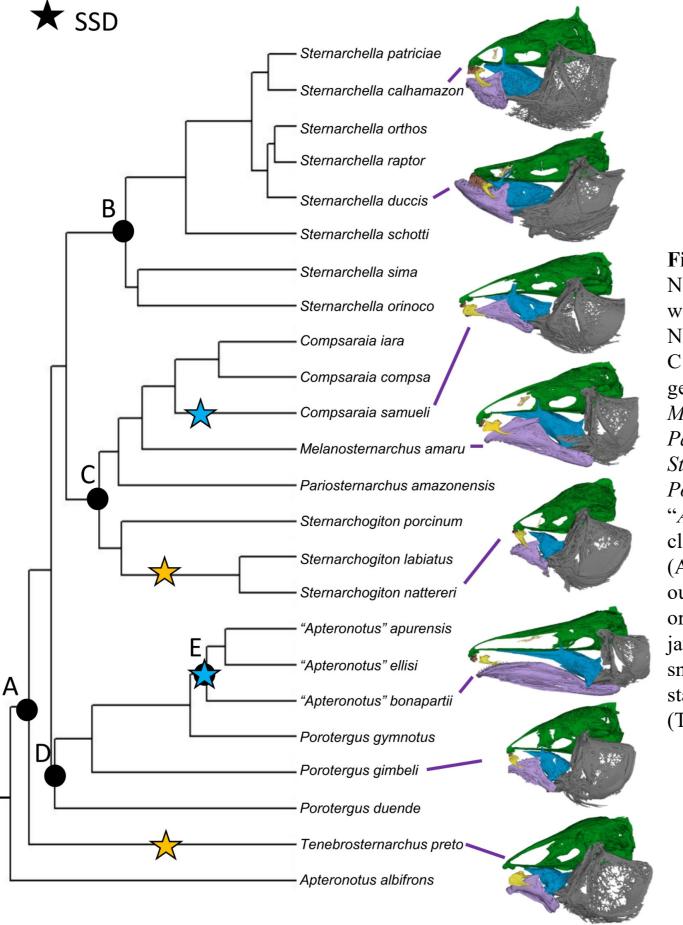
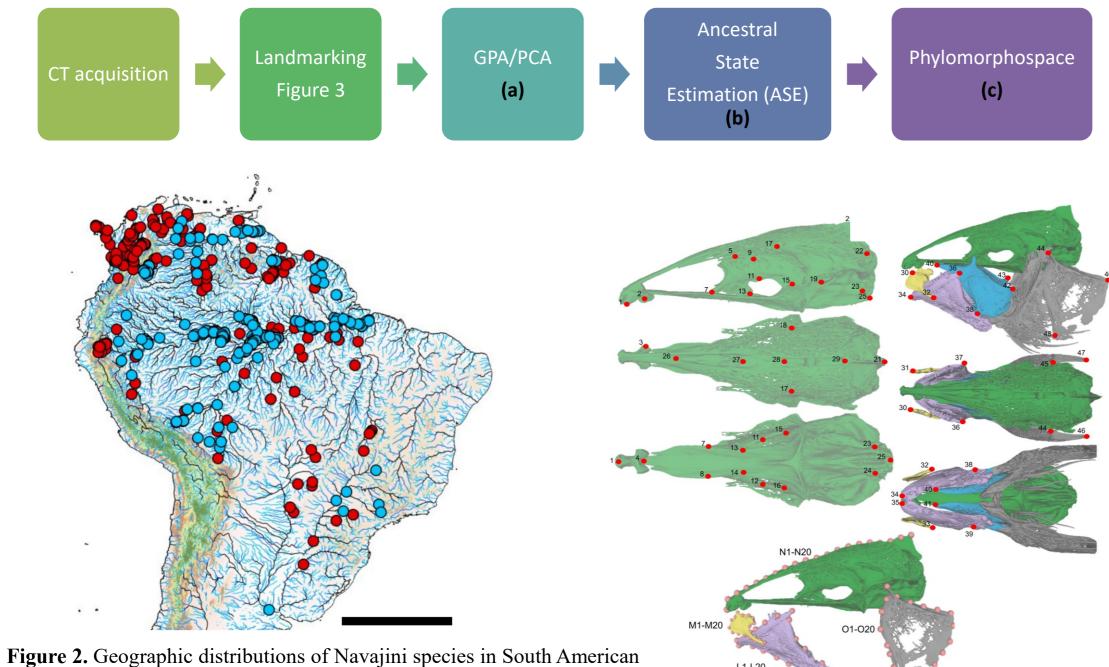


Figure 1. Phylogeny of Navajini highlighting clades with SSD (stars). A = Navajini. B = *Sternarchella*. C = clade comprising the genera Compsaraia, Melanosternarchus, Pariosternarchus, and Sternarchogiton. D = *Porotergus*. E = "Apteronotus" bonapartii clade. Apteronotus albifrons (Apteronotini) serves as an outgroup. Increase in number or size of teeth on the oral jaws = yellow star; elongate snout and mandible = blue star. Phylogeny from (Tagliacollo et al. 2024)

- Deep river channels of South America are extreme and understudied ecosystems with unique selective pressures shaping fish evolution (Lundberg and Fernandes, 2007)
- Navajini (Apteronotidae), a diverse clade of electric fishes, show remarkable craniofacial disparity (Figure 1)
- Secondary sexual dimorphism (SSD), notably elongated jaws and teeth in males, observed in central Amazon (Kolmann and Crampton, 2019)
- Ecological separation between river margins and deep channels has likely promoted contrasting adaptive trajectories and species richness patterns
- This study uses microCT imaging, geometric morphometrics (GMM), and phylogenetic analyses to test whether ecological specialization and SSD jointly explain craniofacial evolution in Navajini (Figures 2 & 3)

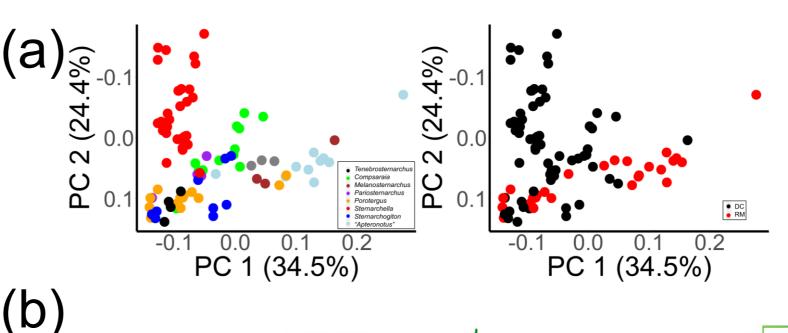
Methods



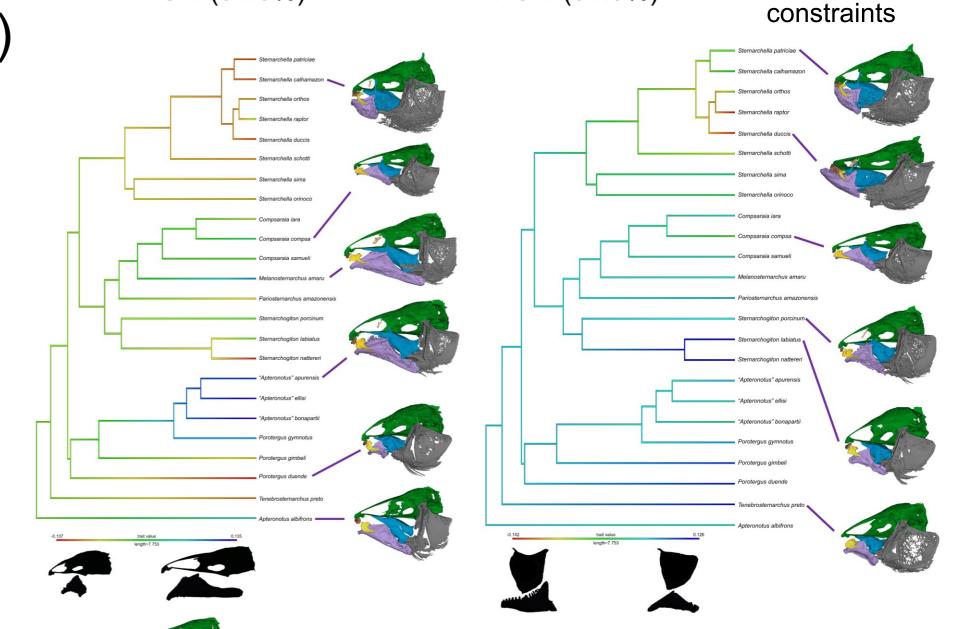
rivers by Strahler stream order (SO). Navajini (blue circles) inhabit large river channels (SO 6-10, black lines). Apteronotini (red circles) Figure 3. Landmark scheme for GMM of skull shape inhabit margins of large rivers and small rivers (SO 4-5, blue lines). Scale bar = 1,000 km.

analysis of Sternarchogiton porcinum.

Results



- PC1: Heterocephaly and lower jaw elongation
- PC2: Mandibular and opercular curvature
- Habitat differences play a secondary role to phylogenetic and developmental



- (c)
- Multiple independent origins of jaw elongation
- SSD drives evolutionary shifts (PC1)
- Ecological specialization drives shifts (PC2)
- Sternarchella stands out as morphologically and ecologically specialized within deep-channel environments.
- Sexual dimorphism amplifies cranial disparity within certain clades ("Porotergus")

Discussion

- Ecological divergence and sexual selection act together to generate extensive shape variation across the clade (Ford et al., 2022)
- Jaw elongation evolved independently at least three times illustrating repeated adaptive convergence (Albert and Crampton, 2009)
- Sternarchella's unique cranial traits (curved, short jaws, superior mouth position) linked to piscivory and tail-biting behavior
 - Adaptive divergence in feeding strategies
- Pronounced SSD restricted to Amazon Basin where ecological complexity, flooding dynamics, and species overlap may foster sexual selection and trait exaggeration
- "Apteronotus" bonapartii group exemplifies diversification through ecological opportunity
 - Frequent river capture events and habitat fragmentation in small rivers promote dispersal and niche exploitation (Albert et al., 2020)

References

Albert, J. S., and Crampton, W. G. R. 2009. A new species of electric knifefish, genus Apteronotus (Gymnotiformes: Apteronotidae), from the Amazon Basin, with comments on ecological specialization and sexual dimorphism. Zootaxa 2291: 1-19. Albert, J. S., Tagliacollo, V. A., and Dagosta, F. C. P. 2020. Diversification of Neotropical freshwater fishes. Annual Review of Ecology, Evolution, and Systematics 51: 27–

Ford, J. K., Tagliacollo, V. A., Albert, J. S., and Sidlauskas, B. L. 2022. Evolution of body shape in electric fishes (Gymnotiformes): ecological diversification and convergence in South American rivers. Evolution 76(3): 589-606.

Kolmann, M. A., and Crampton, W. G. R. 2019. Functional morphology of feeding in Neotropical electric fishes (Gymnotiformes): diversification through trophic innovation. Biological Journal of the Linnean Society 128: 635–652. Lundberg, J. G., and Fernandes, C. C. 2007.A new species of the South American electric fish genus Sternarchella (Teleostei: Apteronotidae) from the upper Rio Negro, Brazil. Proceedings of the Academy of Natural Sciences of Philadelphia 156: 1–18.